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Effects of occlusal splint therapy on opposing tooth tissues, filling materials and restorations

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Abstract

Background: Little is known about the effect of the type of splint material, heat-cured PMMA (HC) or chemical-cured PMMA (CC) on the wear of opposing tooth surfaces.

Objective: The aim of this in vitro study was to evaluate two-body wear of dentin, enamel, glass-ceramic or one of four resin composites when opposing splint materials, namely ProBase HC and CC.

Methods: The two-body wear of bovine dentine, bovine enamel, glass-ceramic IPS e.max CAD (EMAX) and four composites (Filtek Z250 [Z250], Clearfil AP-X [AP-X], Clearfil Majesty Posterior [CMP], Filtek Supreme XTE [FSE]) opposing three antagonists (HC and CC and stainless steel as control) were evaluated in the ACTA wear machine. In addition, all the surfaces were evaluated with scanning electron microscopy.

Results: The highest average wear was observed in the case of dentin. The lowest average wear was found EMAX. In every case—except for EMAX—the wear rate was higher with HC than with CC (all differences being statistically significant).

Conclusions: The level of wear of enamel, dentin and various resin composites was higher in contact with HC than in CC, the wear of dentin being the highest. In the case of a patient with no or little tooth wear or whose teeth are restored with composite material or glass-ceramic, the splint HC might be preferred because of its better durability. However, when the splint is in contact with opposing dentin preservation of the dentin, CC might be the best choice.

KEYWORDS

attrition, bruxism, PMMA, splint, tooth wear

1 | INTRODUCTION

Occlusal splints are an important tool in the management of bruxism and temporomandibular disorders. Hard or soft splints are used to protect not only the patients' teeth, but also all kinds of restorations against wear or fracture. The hard acrylic resin-based splints are either chemically cured or heat/pressure processed. Thus, soft or resilient splints manufactured from polymers like ethylene-vinyl acetate (EVA) can be used to produce a flexible and pliable splint. The hard acrylic occlusal splints appear to have several advantages over their soft counterparts. The fit of hard splints is generally more stable and more retentive and adjustment to the occlusal surface is possible. They contain less porosity and are easy to clean and to repair if needed.[1] Although clinician's skills and experience play a major role in designing and fabricating the best splint for each individual patient, the choice of the material is also important, especially when the therapy is planned for a long period of time. Hard splints are recommended if there is a need to reduce tooth wear and protect the restorations. However, there is to our knowledge little information available on the wear of teeth or restorations induced by contact with the splint material.

Hard acrylic resin-based splints are either chemically cured or heat/pressure and are in general polymethyl methacrylate (PMMA) based.[2] PMMA is cured from methyl methacrylate by the additional polymerisation reaction, which is activated by heat (heat-cured polymethyl methacrylate [HC]) or by chemical activators, such as dimethyl-p-toluidine (chemical-cured polymethyl methacrylate [CC]).[3] The difference between the HC and CC is mainly the degree of conversion of the monomers, where the CC has a higher content of unwanted rest monomer. The wear rate of different splint materials was investigated previously,[4] showing different wear rates for PMMA-based materials. An optimal splint material should wear faster (has higher wear rate) than opposing tooth material and restorative materials to prevent destruction.

Since interaction of the teeth or restoratives during bruxism is a typical two-body wear process, we investigated this in an in vitro study using simulated two-body wear. The aim of this in vitro study was to evaluate two-body wear of dentin, enamel, glass-ceramic or one of four resin composites when opposing splint materials, namely ProBase HC and CC. The null hypothesis is that there is no difference between HC and CC splints on opposing materials.

2 | MATERIALS AND METHODS

The materials used in the study, their manufacturers and batch numbers are shown in Table 1. Two-body wear was evaluated with a wear machine developed by the Academic Centre for Dentistry Amsterdam.[5] In short, the wear machine was equipped with two wheels of different diameters, 48 and 19 mm, which rotated in the same direction with about 15% difference in the circumferential speed while being in close contact with each other (Figure 1). The two-body wear was determined by full contact of the specimen wheel with the antagonist wheel. The specimens were mounted in the wheel in such a way that the specimens were not only worn down but were also subjected to other compressive and tensile forces that might have an effect on the fracture resistance of the tested materials. This was also used previously.[6,7] The specimen wheel accommodated the following materials (in duplo): bovine dentine, bovine enamel, Filtek Z250 (Z250), Clearfil AP-X (AP-X), Clearfil Majesty Posterior (CMP), Filtek Supreme XTE (FSE) and glass-ceramic IPS Emax CAD (EMAX). Three kinds of antagonist wheel were used as follows: stainless steel (SS), hand-processed HC and CC (Table 1). The SS antagonist wheel had an extra hardened outer surface, which is the standard of the ACTA wear protocol[5] and which is also described in ISO/TS 14569. The specimen wheels were stored in water at RT throughout the experiment. The specimen wheel and the antagonist wheels were kept in the water for two months prior to the experiment. The diameter of the antagonist wheels was measured at the start and the end of the two-body wear test. The wheels were pressed against each other with a spring force of 15 N. A test run consisted of 200 000 cycles rotating at the speed of 1 Hz.

TABLE 1 Properties of the materials used in the experiment according to the manufacturers data

Code	Material	Composition	Batch/exp/colour
Z250	Filtek Z250[a]	Bis-GMA, UDMA, Bis-EMA, zirconia, silica	N514907 2016-07/A2
AP-X	Clearfil AP-X[b]	Bis-GMA, TEGDMA, silanated barium glass filler, silanated silica filler, silanated colloidal silica, dl- Camphorquinone	1098AA 2008-04/A3
CMP	Clearfil Majesty Posterior[b]	Hydrophobic matrix monomer, glass filler, alumina nano-filler	1076AG 2016-09/A2
FSE	Filtek Supreme XTE[a]	Bis-GMA, UDMA, TEGMA, bis-EMA, zirconia filler, silica filler	N519329 2016-01/A2
EMAX	IPS e.max Ceram[c]	Glass ceramic, $Ca_5(PO_4)_3$	X36997 HTA2/B40
CC	ProBase chemical-cured polymethyl methacrylate[c]	Powder: polymethylmethacrylate, softening agent, benzoyl peroxide, catalyst, pigments; liquid: methylmethacrylate, dimethacrylate, catalyst	26515 03-2016 Liquid 33178 08-2018 Powder
HC	ProBase heat-cured polymethyl methacrylatec[c]	Powder: polymethylmethacrylate, softening agent, benzoyl peroxide, pigments; liquid: methylmethacrylate, dimethacrylate (linking agent), catalyst	531480 07-2021 Liquid

[a]3M ESPE, Seefeld, Germany.
[b]Kuraray Dental, Tokyo, Japan.
[c]Ivoclar Vivadent AG, Schaan, Liechtenstein.

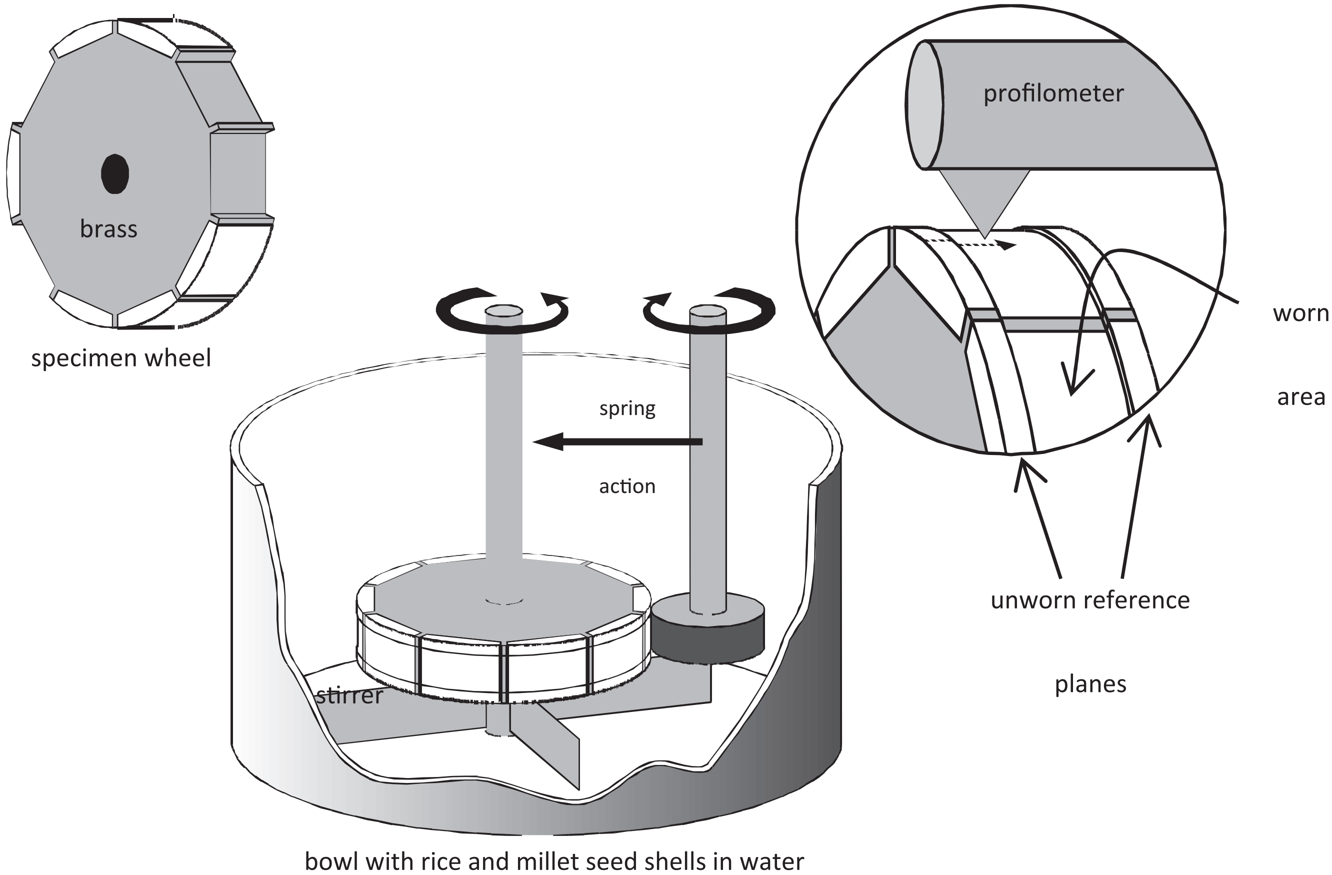

FIGURE 1 Schematic representation of the various steps in the wear experiment. Upper left: Specimen wheel with the specimens cured and glued in the wheel. Middle: Antagonist wheel and specimen wheel rolling over each other to produce wear. Upper right: Profile tracings from one unworn reference to the other across the worn surface to measure wear.

TABLE 2 Average two-body wear rate and standard deviation (STD) of the dentin, enamel, Filtek Z250 (Z250), Clearfil AP-X (AP-X), Clearfil Majesty Posterior (CMP), Filtek Supreme XTE (FSE) and porcelain EMAX (EMAX) with stainless steel (SS), heat-cured polymethyl methacrylate (HC) and chemical-cured polymethyl methacrylate (CC) as antagonist

	Dentin	Enamel	Z250	AP-X	CMP	FSE	EMAX
SS	150.9 (38.1)^{aA}	1.8 (0.6)^{bB}	2.2 (1.7)^{bB}	1.7 (1.2)^{bB}	1.9 (1.4)^{bB}	2.0 (1.0)^{bB}	1.4 (1.0)^{abB}
HC	24.1 (10.0)^{bA}	3.1 (3.0)^{aB}	4.7 (3.5)^{aB}	4.7 (4.6)^{aB}	4.3 (3.7)^{aB}	4.4 (4.1)^{aB}	1.6 (1.5)^{aB}
CC	2.7 (2.7)^{cA}	1.2 (0.9)^{bB}	0.8 (0.8)^{bB}	0.6 (0.8)^{bB}	1.1 (0.9)^{bB}	0.8 (0.6)^{bB}	0.8 (0.7)^{bcB}

Small letters—no statistical differences within antagonists SS, HC, CC.
Capital letters—no statistical differences within materials in specimen wheel.

After the experiment, 10 tracings (n = 10) were taken at fixed positions on the worn surfaces of the specimens (PRK profilometer No. 20702, Perthen GmbH) to determine the loss of material and standard deviations were calculated from these profiles. The worn surfaces were observed by Scanning Electron Microscopy (SEM) at ×5000 (EVO® LS 15, Analytical environmental SEM; Zeiss). SEM specimens were made indirectly from epoxy resin (Araldite; Ciba-Geigy), which was poured into a polyvinylsiloxane impression, and were gold sputtered for electron-conductivity.

One-way and two-way ANOVA and Tukey's *post hoc* test ($p < .01$) were carried out to record any differences in the wear rate values between the various materials and the antagonist wheel for the two-body wear. The software used was SIGMA STAT 3.1 (Jandel Software).

3 | RESULTS

The wear rates of 7 materials, that is dentin, enamel, Z250, AP-X, CMP, FSE, EMAX, against three different antagonist wheels: SS, hot (HC) and cold (CC) cure HC PMMA was determined. The wear rates, their standard deviation and the statistical analysis are summarised in Table 2. The highest average wear rate was observed for dentin and differed between the wheels SS 150.9, HC 24.1 and CC 2.7 μm, while the lowest average wear rate was observed for EMAX (1.4, 1.6 and 0.8 μm for SS, HC and CC, respectively). All materials demonstrated more wear opposing HC than in CC (see Figure 2), and all observed differences were statistically significant (see Table 2).

SEM analysis showed that regardless of the antagonist wheel used, the different materials demonstrate similar topographic patterns (Figure 3). In general, a relative smooth surface was observed, with some minor differences in topology between the materials and antagonist wheel (CC or HC). During the wear experiment, not only wear of the dental materials was observed but also the diameter of the antagonist wheel diminished during the wear test. The reduction in diameter was for the CC 80 μm and for HC 60 μm after 3 experiments.

4 | DISCUSSION

The aim of this study was to assess the two-body wear between two hand-processed oral splint materials, HC and CC against dentin, enamel and the restorative materials: glass-ceramic and four resin composites. The stainless steel wheel served as the control experiment. The results showed significant differences in the wear produced by HC and CC splint material, and in every analysed case, the resulting wear was greater with HC than CC. The highest wear rate was observed on opposing dentin (10 times greater for HC than CC) while the lowest average wear was seen on glass-ceramic. Based on the present study, the null hypothesis that is no difference between HC and CC splints on opposing materials could be rejected. The different wear behaviour of composite resin compared with glass-ceramic or enamel can be explained by the hardness of the splint materials and differences in the homogeneity of materials. The PMMA materials are relatively soft and glass-ceramic and enamel have a homogeneous hard surface resulting in a uniform wear. Resin composites have a more heterogeneous composition with hard filler particles embedded in a relatively soft resin matrix. In contact with the soft PMMA, the resin matrix will preferentially wear exposing filler particles that can be dislodged.

In the United States alone, 1.6 million splints are annually prescribed to patients suffering from bruxism.[8] In Germany, dentists and other dental specialists make approximately 30 occlusal splints a year to treat temporomandibular disorders.[9] That is why it is extremely important to determine the optimal technique for producing effective splints. Reyes-Sevilla et al. measured the wear of a splint made of hand-processed chemical-cured PMMA, polyamide-based, milled PMMA and printed PMMA against composite materials. According to that study, printed PMMA and polyamide-based splints exhibited less wear than the chemical-cured or milled PMMA splints.

Splints are generally used to protect teeth from extensive wear. However, it is not clear how printed and polyamide splints affect the wear of exposed dentin in the case of patients with bruxism. Tooth wear classification distinguishes several degrees, and three of those specify the degree of dentin wear.[10] Prevalence data show that mild and moderate tooth wear is a common condition in the Dutch adult population, while severe or extreme tooth wear is rare.[11] The patients wearing protective splints during the night can also exhibit exposed dentine. In the case of exposed dentin, a splint made from CC PMMA will be the best choice to prevent accelerated wear of the dentin. For the same reason, the development of printed PMMA splints made from CC PMMA requires additional research on the wear on dentin.

The degree of conversion of MMA to PMMA never reaches 100%, and some MMA remains in PMMA. From the biological perspective, the MMA released into saliva may cause certain negative reactions, such as some redness, swelling and pain of the oral mucosa.[12] There will be less residual monomer in HC than in CC during the initial storage time but insignificant differences during the remainder of the storage period.[13] A study by Engler et al. shows that the differences in elution of residual monomer were material-dependent rather than technique-related, for example hand-processed or printed; still, the maximum elution found was below the specified threshold of ISO standard 20795-1.[14]

The findings of the present study suggest that there is a need for creating a protocol on the choice of splint material meeting particular needs of the bruxing patient. For example, when in the opposing arch the teeth are restored with resin composite, porcelain or are fully in enamel, a HC might be a preferred option because of better biological properties of the material and less wear of the splint. On the other hand, patients with exposed dentine will benefit from a less abrasive splint material to prevent excessive dentin wear. In a two-body wear situation, the combined wear of the applied materials should be evaluated. Certain materials will not exhibit much wear themself but may be very aggressive for the opposing surface. In this study, the more abrasive character of HC compared with CC is reflected by a higher wear resistance of the HC wheel compared

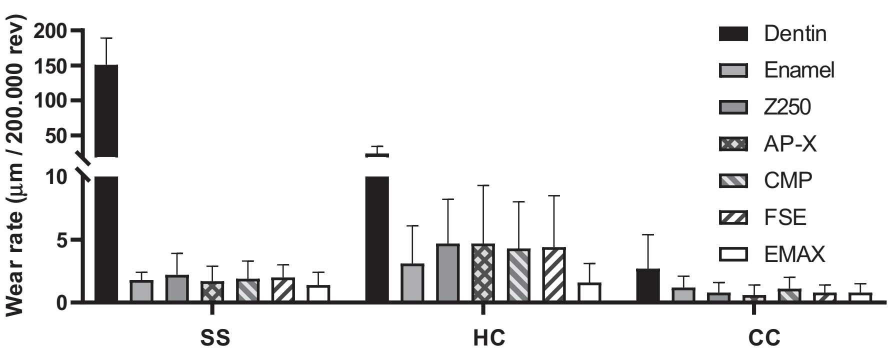

FIGURE 2 Graphical representation of the two-body wear rate of the materials with stainless steel (SS), heat-cured polymethyl methacrylate (HC) and chemical-cured polymethyl methacrylate (CC) as antagonist.

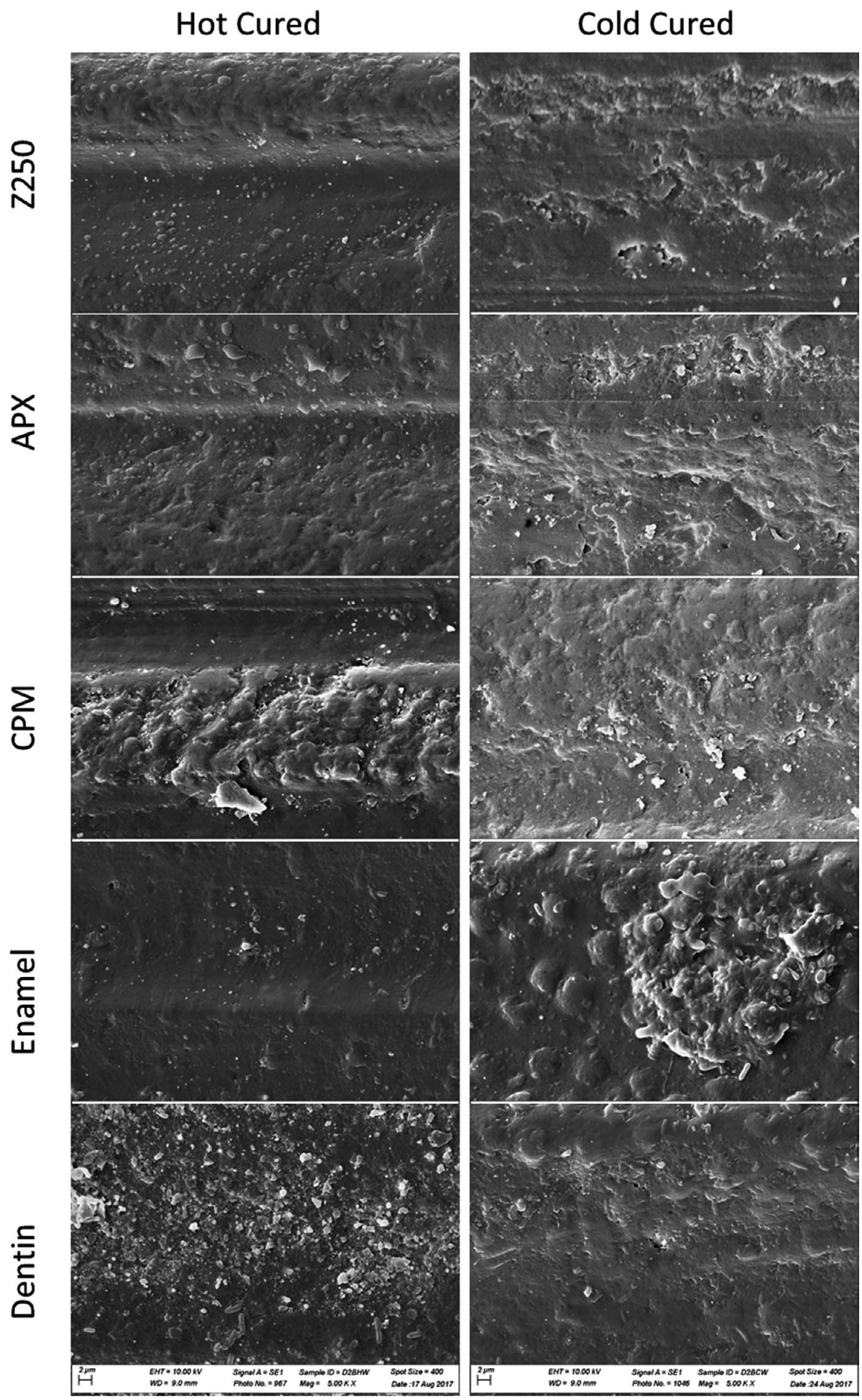

FIGURE 3 Representative SEM images (5000×) of the specimen of Z250, AP-X and CMP together with Enamel and Dentin after the two-body wear experiment with antagonist wheel of CC and HC, respectively.

with the CC wheel. Therefore, a CC splint will require more maintenance and have a shorter service life than the HC splint. The dental situation of each individual patient will determine the choice of the splint material.

It is a limitation of this study that it was carried out as an in vitro study. However, there are no clinical data available on this topic, these results are important for clinicians regarding the wear of teeth or restorations induced by contact with the different splint materials.

5 | CONCLUSIONS

Within the limitation of the in vitro study, it can be concluded that the level of wear of enamel, dentin and various resin composites was higher in contact with HC than in CC, the wear of dentin being the highest. Therefore, the choice of splint materials ought to be based on the specific clinical needs of the bruxing patient. In the case of a patient with no or little tooth wear or whose teeth are restored with composite material or porcelain, the splint HC might be preferred because of its durability. However, when the preservation of the dentin is of paramount importance, CC might be the right choice.

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CONFLICT OF INTEREST

The authors declare that they received no funding for this study. The have also stated explicitly that there are no conflicts of interest in connection with this article.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to the conception, drafting and critical revision of this work. All authors have approved the final version for publication and are fully accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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